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Domestic scale vermicomposting for solid waste management

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Abstract

Background: Vermicomposting has recently been recognized as one of the most appropriate methods to stabilize organic waste. In terms of a system for waste management, vermicomposting is sustainable, economically viable, and without detrimental effects to human health or to the environment. The aim of this study was to evaluate the process of vermicomposting using an indigenous species of earthworms (*Eisenia fetida*) on a small domestic scale as a system for waste management.

Results: This study was carried out as an experiment using the following procedure: a plastic container was prepared for vermicomposting; then, a bed was prepared in a ready container with a layer of initial bedding, sieved garden soil, and compostable waste. It was inoculated with *Eisenia fetida* earthworms. Samples were taken after 30 and 90 days of vermicomposting, and measurements were taken for the following parameters: percentage of organic matter, phosphorus, total carbon, total nitrogen, moisture content, ash, electrical conductivity, and pH. Results for percentage of organic matter, phosphorous, ash, total carbon, total nitrogen, carbon/nitrogen ratio, electrical conductivity, moisture content, and pH of mature compost after 90 days were 42 ± 2.8 , 53 ± 0.17 , 22 ± 0.170 , 1.12 ± 0.003 , 20 ± 0.25 , 2.8 ± 0.6 , 1, 200 ± 200 cSu, $56 \pm 5.5\%$, 8.3 ± 0.2 , respectively, and all these parameters except moisture content were compared with the standards.

Conclusion: According to these results, vermicomposting of municipal biodegradable waste by homeowners can be recommended as the best and most suitable method for solid waste disposal. This determines small-scale domestic vermicomposting as a suitable method for solid waste management. Reducing domestic waste at the source is an effective way to implement the main priorities of a waste management system in terms of its economy and its impact on the environment.

Keywords: Solid waste management, Vermicompost, Municipal solid waste, Domestic scale

Introduction

Concerns about the state of the environment and problems of solid waste disposal are issues that are increasingly demanding attention globally. In Iran, serious environmental problems and economic concerns have arisen from a lack of appropriate technology and facilities, urban diseases, solid waste disposal in unsanitary and undesirable ways, and open dumping of waste in and around cities (Abdoli 1993; Yousefi et al. 2004). Thus, research into possible solutions to the problems of urban waste management by the production of compost fertilizer from biodegradable waste could reduce environmental problems

and constitutes a cost-effective step towards a more effective waste management system (Yousefi et al. 2008). Operations and research have been done in the field; 200 large-scale factories were reportedly built in Europe in 1975 to produce composted fertilizer. The first composting factory was constructed and launched in Isfahan in 1969 and then in Tehran in 1972, and similar factories have recently been constructed in other Iranian cities including Kermanshah, Mashhad, Tabriz, Rasht, and Babol (Zazouli et al. 2010). There are many different methods to produce compost fertilizer using earthworms. One of the most important earthworm families is Lumbricidae, and one of its members, *Eisenia fetida* can be used to stabilize organic waste by the process called 'vermicomposting' or composting with worms (Asgharnia 2003; Abrahimi et al. 2009). Aristotle named earthworms 'territory intestines,' but 22 centuries later,

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Charles Darwin showed how earthworms enhance soil fertility by turning the soil. Darwin estimated that 10 to 18 tons of dry soil passes through earthworms' guts every year on farmland. The essential nutrients of potassium and phosphorus are brought to surface layers of the soil by this action induced by earthworms. Nitrogen and some of its products can enter into the layer under the soil. Earthworms also bring molds up to the soil surface and grind them, pulling down leaves, and other organic matter into their burrows to under layers of the soil, near plants' roots (Asgharnia 2003; Zazouli et al. 2010).

There are two types of vermicomposting: small-scale models (large and small cylindrical composting makers and containers with four or three units) and large-scale models (windrow method, bioreactor systems, outer bin, and plane systems) (Zazouli et al. 2010). Composting has currently been developed into a simple but efficient biotechnology for recycling a wide range of organic waste using species of earthworms. According to the growing popularity of this biotechnology, studies have been done on different aspects of waste recycling by composting for agricultural purposes (Gunindra 2012).

Several studies have been reported from around the world as well in Iran, in terms of consumption of organic residue such as sewage sludge, animal remains, industrial and agricultural wastes by earthworms and converting it to 'vermicompost' on a small-scale methods. The following reports have contributed to research in the field of composting: Khalfi et al. (2004) from sugar beet waste, Parvaresh et al. (2004), Gupta and Garg (2008) from municipal sludge waste, Tahir and Hamid (2012) from different types of coconut wastes, Hemalatha (2012) from mixing municipal solid waste and sewage sludge, Alidadi et al. (2006), Kaviraj and Sharma (2003) from animal manure, and Yousefi et al. (2008) from domestic waste. In addition, Hernandez et al. (1999) used cow manure as a substrate for earthworms (*E. fetida*) for vermicomposting, and Dominguez et al. (2000) reported on processing sludge by earthworms (*E. fetida*) to produce vermicompost.

Research has reported that earthworms can quickly decompose and stabilize animal manure and, in doing so, they increase soil biochemical characteristics making it more suitable for plant growth (Atiyeh et al. 2000a, 2000b). The largest share of total costs in a solid waste management system is related to the collection and transportation (80% to 70%), so any process that reduces solid waste at source should be considered as a viable option by home owners and related organizations; thus, recycling waste at the source of its production (and converting it into valuable material) presents a very appropriate focus for further discussion (Singh et al. 2011; Sudhir Kumar et al. 2010; Tchobanoglous et al. 1993). Investigations made in this field in Iran have mostly been concerned with vermicomposting outsourced waste materials such as

animal dung, industrial and agricultural wastes, and municipal sewage sludge rather than domestic waste and, thus, have not contributed to a shift in the structure of solid waste management systems. So, this study was done in an attempt to restructure the system of solid waste management by investigating small-scale vermicomposting on site by producers of the waste.

Methods

The experiment for this study was conducted as follows: A cylindrical plastic container, 45 cm in diameter and 30 L in volume was prepared. Several small holes (approximately 1 cm in diameter) were made in the sides of the container to provide aeration and to avoid water logging. A layer of sand about 5-cm thick was bedded into the container and then topped with 15 kg of compostable household organic waste which had been chopped to reduce its size and volume. It should be noted that to avoid disordering in the vermicompost production process, materials considered unacceptable to earthworms including citrus, garlic and onions, meat, dairy products, fish and beans were separated and removed. After, 50 adult earthworms were inoculated into the experimental set (vermicomposting), and then a little water was added to the initial worm bedding to maintain its moisture content and was spread over the bedding material in the container. It was then topped by 2.5 cm of sieved garden soil. The surface of the bed was covered. The organic waste was turned periodically (once every few days) for better aeration and to mix its contents. Earthworms and the initial substrate were prepared by the Sustainable Agricultural Office, Iran. The composting process was allowed to continue for periods of 30 and 90 days.

Samples were collected after 30 and 90 days and dried at 75°C for 24 h (1 kg per volume) and finely powdered. For observing and measuring parameters for changes due to earthworm activity, samples were taken from the soil at the start of the experiment. The results are presented in Table 1.

Analytical methods

All parameters, including organic matter, were determined by burning the dried remains at 550°C for 1 h, and the ash content was measured by the following equation: $1.8 \text{ C (total carbon)} = 100 - \text{ash\%}$; the total carbon was evaluated by burning the dried remains at 750°C for 2 h; total nitrogen was determined by the Macro-Kjeldahl method, pH by a modified Arhat and Buryn method, electrical conductivity by the Slurry method 1:5, phosphorus by the burning dried remains method and combined with hydrochloric acid extraction, and total phosphorus was determined by the colorimetric method (with ascorbic acid); moisture content was measured by drying at 105°C for 24 h according to

Table 1 Average measured parameters in the initial soil and 30 and 90 days of vermicomposting

Parameters (g/100 g)	Raw solid waste	30th day vermicompost	90th day vermicompost	Comparison with WHO standard		Comparison with ISIRI standard			
				Standard rate	P value	Grade 1		Grade 2	
						Standard rate	P value	Standard rate	P value
Organic matter	3.5 ± 24	2.5 ± 33	2.8 ± 42	40 to 50	0.423	Min: 35	0.035	Min: 25	0.0264
Ash	0.02 ± 59	0.026 ± 56	0.17 ± 53	50 to 55	0.891	Max: 50	0.562	Max: 50	0.562
Total C	0.02 ± 29	0.026 ± 27	0.17 ± 22	8 to 50	0.08	Min: 25	0.0867	Min: 15	0.044
Total N	0.005 ± 0.3	0.003 ± 0.9	0.003 ± 1.12	2 to 3	0.012	1.55 to 1.66	0.0431	1 to 1.5	0.095
C/N ratio	0.3 ± 45	0.2 ± 30	0.25 ± 20	20 to 25	0.345	15 to 20	0.11	10 to 15	0.03
Total P	0.1 ± 1.2	0.2 ± 1.9	0.26 ± 2.8	0.02 to 0.03	0.075	1 to 3.8	0.173	0.3 to 3.8	0.0731
Ec (dS m ⁻¹)	332 ± 45	900 ± 123	12,000 ± 200	-	-	-	-	-	-
Moisture content	-	-	5.5 ± 56	30 to 50	0.043	Max: 15	<0.001	Max: 35	0.034
pH	0.3 ± 7.9	0.17 ± 8.2	0.2 ± 8.3	6 to 9	0.09	6 to 8	0.048	6 to 8	0.048

Ec, electrical conductivity.

standard test methods (APHA et al. 1995; Gotas 1956; Theroux et al. 2001; Taye 1986; Thompson 2001). Measuring was repeated five times for each parameter.

Results

Table 1 presents an overview of the average parameters that were measured on raw solid waste from 30 and 90 days of vermicomposting. Comparisons of the parameters to standard rates were made for percentage of organic matter, ash, total carbon, total nitrogen, and phosphorous; the results are presented in Table 1.

Averages for parameters were compared with the standard rates of the World Health Organization (WHO) and the Institute of Standards and Industrial Research of Iran (ISIRI 2011) using the one-sample *t* test with a significance level $\alpha = 0.05$. It is noteworthy that the averages for the parameters, or maximum or minimum of standards, were considered as test values. According to the results of the statistics tests, the properties of the standard compost and related interpretations of the percentages for the parameters are presented as follows:

Organic matter

The average amount of organic matter in mature vermicompost was less than the standard rate of WHO, but this difference was not significant (i.e., it was consistent with the standard). It was also more than the minimum standard rate of ISIRI (vermicompost grades 1 and 2), showing consistency with the standard.

Ash

The average amount of ash in the mature vermicompost was more than the average standard rate of WHO and the maximum standard rate of ISIRI (vermicompost grades 1 and 2), but this difference was not significant (i.e., it was consistent with these standards).

Total carbon

The average amount of total carbon in mature vermicompost was less than the standard rate of WHO and the minimum standard rate of ISIRI (vermicompost grade 1), but this difference was not significant (i.e., it was consistent with these standards). Also, its average amount was less than the minimum standard rate of ISIRI (vermicompost grade 2), showing consistency with these standards.

Total nitrogen

The average amount for total nitrogen in mature vermicompost was less than the average standard rates of WHO and ISIRI (vermicompost grade 1), but this difference was significant (i.e., it was not consistent with these standards). Also, the average amount was less than the minimum standard rate of ISIRI (vermicompost range 2), but this difference was not significant, and it was consistent with the standard.

C/N ratio

The average amount of C/N ratio in mature vermicompost was less than the standard rate of WHO, but this difference was not significant (i.e., it was consistent with the standard); the average was more than the standard rate of ISIRI (vermicompost grade 1), and this difference was not significant (i.e., it was consistent with the standard).

Phosphorus

The average amount of phosphorus in mature vermicompost was more than the average standard rate of WHO and the standard rate of ISIRI (vermicompost grades 1 and 2), but this difference was not significant (i.e., it was consistent with these standards).

Moisture content

The average amount for moisture content was more than the standard rates of WHO and ISIRI (vermicompost grades 1 and 2), but this difference was significant (i.e., it was not consistent with these standards).

pH

The average pH level in mature vermicompost was more than the average standard rate of WHO, but this difference was not significant (i.e., it was consistent with the standard). The average was more than the standard rate of ISIRI (vermicompost grades 1 and 2); this difference was significant (i.e., it was not consistent with the standard).

Discussion

Comparison of the quality of mature vermicompost (90 days) with the WHO standard for evaluating good quality compost and with the ISIRI standard for vermicompost grades 1 and 2 in terms of selected parameters of organic matter, ash, percentage of total carbon, C/N ratio, and pH was determined, resulting in good quality vermicompost (grade 1) with a confidence level of 95%. However, according to the WHO standard, the pH of the compost was evaluated as good quality, but it did not comply with first grade compost standard according to ISIRI. The total nitrogen content of the compost was in compliance with second grade compost according to standards; in terms of moisture content, it was not consistent with the first and second grade compost standards.

The results of the research by Kaviraj and Sharma (2003) showed that the species of earthworms (*Lampito mauritii*) were capable of converting organic solid waste to manure, which is a valuable compost that can be used to modify the structure of soil. Singh et al. (2011) indicated that the vermicompost produced from municipal waste is a significant option for solid waste management prior to land use. Also, vermicompost is rich in plant nutrients and free of pathogens, making it suitable for application in agriculture. Utilization of vermicompost in agriculture will facilitate the growth of the country's economy by reducing the use of chemical fertilizer and addressing problems associated with land degradation.

These results confirm that the quality of mature vermicompost in the study was efficient and in compliance with recognized standards to improve soil and soil fertility. It has been reported that the amounts of organic matter, nitrogen, phosphorus, pH, and the C/N ratio of production of vermicompost from municipal sewage sludge were 36.4%, 1.04%, 0.112%, 7.5, 22.6, respectively, by Parvaresh et al. (2004). However, a comparison of those results with the findings of this study indicates that the vermicompost produced by organic household waste contained high levels of nutrients and was of better quality than the vermicompost produced

by municipal sewage sludge in terms of improving soil fertility and stimulating plant growth. Khalfi et al. (2004) also found similar results in their study. Results showed that the C/N ratio in vermicompost was better than that produced by aerobic composting and vermicomposting sugar beet waste. In addition, the amount of nitrogen and phosphorus in the vermicompost was more than that in aerobic compost, making it more appropriate for plant growth. Moreover, some other researchers have found similar results (Hernandez et al. 1999; Atiyeh et al. 2000b; Dominguez et al. 2000).

Gupta and Garg (2008) reported a high quality compost produced by vermicomposting using initial materials of sludge mixed with cow dung (30% to 40%). The result of Hemalatha (2012) revealed that earthworms could decompose mixed municipal solid waste and industrial sludge more quickly to produce compost with low toxicity and high value, which can be used as a natural fertilizer to improve soil structure.

The American Environmental Protection Agency expressed that solid waste management options are based on four priorities: the first priority was to reduce waste at source and re-use it, and the second priority was to implement practices of recycling and composting (Tchobanoglous et al. 1993). However, according to the report of the Iran Interior Ministry in 2005, most domestic solid waste constitutes compostable materials (62% to 64%), and a smaller part of it is non-compostable materials such as plastic, glass, and metals (36% to 37%) (Zazouli et al. 2010). Therefore, composting degradable material at source in households presents a good solution for implementing the first and second priorities, and in doing so, it eliminates municipal waste management problems. If training homeowners to adopt this practice is done properly by organizations such as municipalities, it can be a very effective step towards protecting the environment. However, the application of this practice also serves to preserve the environment and eliminate other costs incurred by waste management systems. As reducing solid waste at source (by converting degradable materials to fertilizers at the point of waste production source) can reduce collection and transportation costs of solid waste management, it would cover the entire cost of a waste management system by about 60% to 70% (Tchobanoglous et al. 1993). Furthermore, homeowners can produce compost in a cost-effective way from unvaluable waste material, with more economical value than chemical fertilizer or aerobic compost for agricultural purposes.

Conclusions

In summary, according to the above discussion and in order to properly plan for efficient management of the environment and the economy and to implement the

priorities of municipal solid waste management especially in terms of reducing household waste at the source of production, vermicomposting household waste presents a very effective solution and an appropriate management of municipal solid waste by homeowners.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MP designed the protocol and supervised the entire work. TK conceived the study, participated in its design and coordination, and drafted manuscript. KS carried out the overall studies on vermicompost production and performed the statistical analysis. All authors read and approved the final manuscript.

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